STUDY ON CARBONIZATION OF NON WOODY BIOMASS SPECIES

A THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENT FOR THE DEGREE OF

Bachelor of Technology
in
Metallurgical and Materials Engineering

By

ARPIT NAG

Department of Metallurgical and Materials Engineering

National Institute of Technology

Rourkela

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Under the Guidance of

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CERTIFICATE

This is to certify that the thesis entitle, "STUDY ON CARBONIZATION OF NON-WOODY BIOMASS SPECIES" submitted by Mr. ARPIT NAG in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Metallurgical and Materials Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the any Degree or Diploma.

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I wish to record my gratitude to our project coordinators Prof.K.N.Singh and Prof.A.K.Panda for helping me at each and every step in bringing out this report.

I am also thankful to our others teachers who taught me this interesting discipline. Last but not least I thank technical assistant specially Mr. Bhanjo Nayak of metallurgical Dept. and my friends to help me directly or indirectly to complete this project successfully.

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B.Tech
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ABSTRACT

Carbonization of wood for the manufacture of charcoal has been practiced since the beginning of history. The Industrial Revolution brought about a heavy demand for wood charcoal, and up until the late 1800s the largest volume was used by the iron industry. Today, coal derived cokes are used and wood carbonization, and use of distillates, is practiced more in developing countries. Despite the decline of the traditional wood pyrolysis industries, a great deal of technical information regarding cellulose (and lignocellulosic) decomposition kinetics, mechanisms, thermodynamics and byproducts has been acquired using modern analytical techniques. Several different markets provided motivation for the pursuit of this information. Those markets include: activated carbons, textiles, composite materials, fire retardant wood products and energy from biomass and refuse. While much information is available from these works, there exists a gap in knowledge regarding monolithic carbonized wood. Specifically, no studies have been found relating to methods .Biomass, especially wood, has traditionally been an important source of energy particularly attractive nowadays because of its inherent nature of being environmentally friendly and renewable The aims of the present project work have been to characterize the proximate analysis and calorific value of different components of BANMICHAI (non woody biomass species).The second aim was to carbonize the different components in the temperature range of 300-900°C From the experiments we observed that there is a significant increase in the calorific value with increase in the carbonization temperature. Therefore it is evident that for higher carbonization temperature the biomass species i.e. BANMICHAI can suitably be preferred over other conventional sources of energy. Further with increase in the carbonization temperature the fixed carbon (%) was also found to increase. The calorific value obtained from different chars samples are found to be comparable to coal. Any approach towards utilizing the non-woody biomass would be a positive step toward energy and environment crisis.

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Chapter 1

INTRODUCTION

1. INTRODUCTION

Carbonization of wood for the manufacture of charcoal has been practiced since the beginning of history. The Industrial Revolution brought about a heavy demand for wood charcoal, and up until the late 1800s the largest volume was used by the iron industry. Today, coal derived cokes are used and wood carbonization, and use of distillates, is practiced more in developing countries. Despite the decline of the traditional wood pyrolysis industries, a great deal of technical information regarding cellulose (and lignocellulosic) decomposition kinetics, mechanisms, thermodynamics and byproducts has been acquired using modern analytical techniques. Several different markets provided motivation for the pursuit of this information. Those markets include: activated carbons, textiles, composite materials, fire retardant wood products and energy from biomass and refuse. While much information is available from these works, there exists a gap in knowledge regarding monolithic carbonized wood. Specifically, no studies have been found relating to methods by which large pieces of wood can be carbonized while retaining their mechanical integrity. Further, no information relating to the production of large crack-free charcoal as been reported. In addition, no study of the reduction in dimensions of wood as a result of carbonization has been performed. Finally, measurement of resulting char mechanical properties can not be found in the literature. These are some of the questions which have been addressed by this investigation since they have a profound effect on the utility of the materials which have recently been produced from wood precursors The primary goal of the present investigation was to produce monolithic pieces of carbonized wood, free from the cracks normally associated with wood Fuel is basically a source of heat and the usual method of producing heat from fuel is by the process of combustion which is a chemical reaction between the fuel and an oxidant mostly oxygen, oxygen enriched air. However the uses of energy can be broadly divided into four different heads such as:-

- Household energy includes heating, cooling, cooking, lighting and appliances.
- Transportation energy required for different vehicles.

- Industrial energy covers industrial complexes, factories, research and development divisions and trade.
- Health, education and welfare activities take care of large scale administration, water supply, sewage and trash disposal, military forces, hospitals and schools. The energy requirements of most of the developed countries are mainly divided into these four categories.

This demand of energy can be achieved by mainly two kinds of fuels such as:-

- Fossil fuels
- Alternative sources of energy

Chapter 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 What is biomass?

Biomass can be defined as the organic material produced from solar energy by the process of photo-synthesis. The atmospheric carbon dioxide is fixed in the form of biomass as the primary product of photosynthesis in the terrestrial and aquatic regions of earth.

2.2 Types of biomass

Biomass may be divided into 3 categories:-

- Fuel wood
- Organic wastes
- Photosynthesis fuel

Biomass, especially wood, has traditionally been an important source of energy particularly attractive nowadays because of its inherent nature of being environmentally friendly and renewable. Wood has also been considered as a potential feedstock for gasification to produce a mixture of H_2 and CO (singes). In this process, the wood is converted into char as an intermediate product which is subsequently or simultaneously gasified. The wood carbonization in which the high yield charcoal is the principal product is effectively an initial stage in any gasification process. It is characterized by a slow heating rate, a relatively low temperature (600–700 K) and a long residence time. Indeed, the mechanism of wood carbonization shows the presence of several Decomposition phases when the temperature increases. A wood drying phase with elimination of some volatile compounds takes..

2.3 Anatomy and composition of wood

Wood is composed of several polymers which form a complex framework of interconnected elongated hollow cells of specific orientation. Though the anatomy of

every species is in some way unique, a general description is adequate for revealing features of current interest. More detail can be found in the literature.

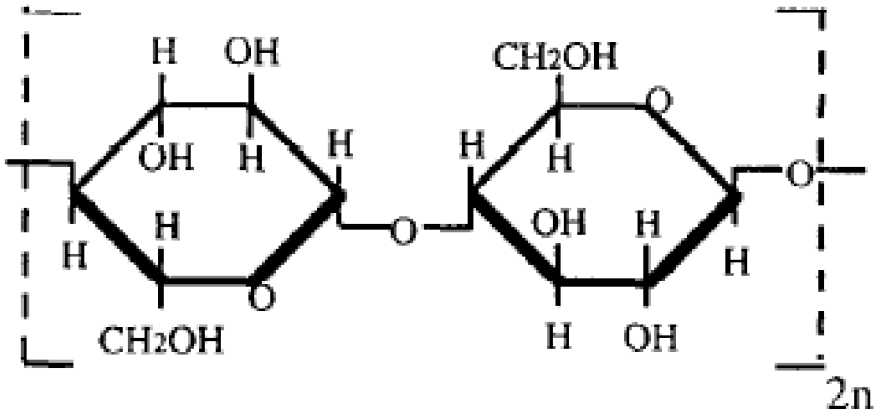


Fig. 2.1. The structure of cellulose, (C 6H 100 5) “3 the primary polymer in wood.

The structure of cellulose, (C 6H 100 5) “3 the primary polymer in wood. Wood provides mechanical strength to the tree swell as performing functions such as liquid transport and food storage. Both hardwoods and softwoods are comprised of elongated tubular cells aligned with the axis of the tree trunk. These are referred to as longitudinal cells, or fibers, and are what gives the wood grain direction. Longitudinal cells vary in length from one species to another and in general are longer in softwoods than in hardwoods. Fiber diameters in softwoods range from 35 to 50 microns, and have an aspect ratio on the order of 100 (based on the hollow cell).

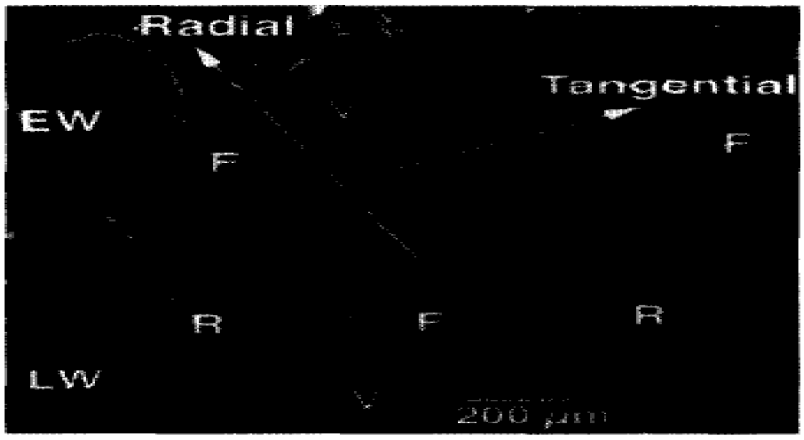


Fig. 2.2. Section of teak (Tectona *grandis)* showing cellular features common to hardwoods. Symbols indicate: EW=earlywood, LW = latewood, V =vessel elements, R = rays, F =fibers. Principal directions indicated by arrows.

Section of teak (Tectona *grandis)* showing cellular features common to hardwoods. Symbols indicate: EW= early wood, LW = latewood, V =vessel elements, R = rays, F =fibers. Principal directions indicated by arrows.

Perpendicular to those is ray cells which are aligned from the center (pith) of the trunk radially outward to the bark (actually stop at the cambium layer). These features are indicated in Fig. 1. There are many more longitudinal cells than ray cells, the proportion varies between species. Softwood ray cells on average occupy z 10% of the wood volume, Hardwood ray cells ~20%.dry weight of wood tissue. The cellulose super structure has a matrix of lower molecular weight polysaccharides called hemicelluloses. Lignin, the third major component of wood tissue, comprises 18-35 wt% of dry wood. It is a three dimensional, highly branched polyphenolic molecule of complex structure and high molecular weight. It permeates cell walls and intercellular regions giving the wood its relatively high hardness and rigidity. Lignin acts as glue which bonds together all wood cells. Wood is anisotropic due to both the cellular morphology and sub-cellular features. On the cellular level, variation in density owing to a ring-porous structure or an abrupt early wood-latewood transition can impart anisotropy. Additionally, the perpendicular orientation of ray cells to longitudinal cells imparts anisotropy to all wood species. At the sub cellular level, alignment of cellulose micro fibrils in the secondary cell wall gives the wood fibers high axial stiffness. These factors all lead to a naturally anisotropic structural system. A convention for labeling the principle directions of wood is shown in above fig .There are many different chemical constituents in wood. Most, by weight, are of an organic nature. If one excludes the minor amounts of minerals and trace metal ions, dry wood has an elemental content of 50 wt% carbon, 44 wt% oxygen and 6 wt% hydrogen. Section of teak (Tectona *grandis)* showing cellular features common to hardwoods.

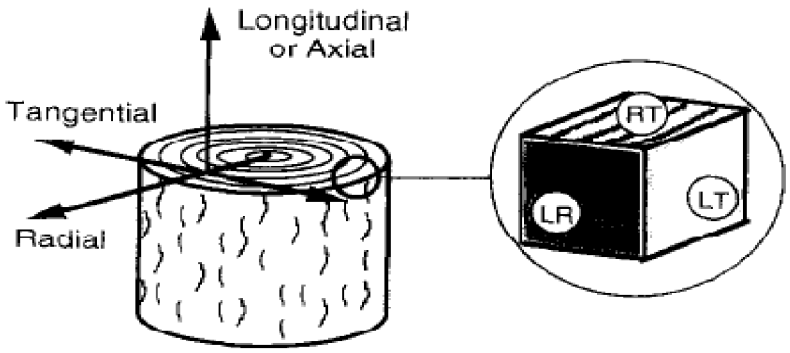


Fig. 2.3. Principle directions used for describing physical and mechanical properties of wood. Inset shows convention for labeling planes.

Principle directions used for describing physical and mechanical properties of wood. Inset shows convention for labeling planes.

During mining and ore dressing operations, especially where very fine grinding is necessary for wet concentrations, a large amount of-0.05 mm fines is generated which are not amenable to sintering because of very low permeability of the bed. They can however be agglomerated by balling them up in presence of moisture and suitable additives like bentonite, lime etc. into 8-20 mm or larger size. These green pellets are subsequently hardened for handling and transport by firing or indurating at temperature 1200-1350^{o}C.

The balling stage is the most important part of the process and determines the strength, size compactness and other pellet properties. The operation is performed in rotating devices like drums, discs (with flange on the rim) and cones, the most used being the former two. The effectiveness of the plain can be increased by fixing daffles inside. The ball formation occurs because of the surface tension of the water forces and collision between particles. Initially, small nuclei of pellets are formed on addition of water and the nuclei grow bigger into balls and then into pellets as the peak of loose grain particles during their travel through the drum which is slightly tilted. The angle of tilt determines the time of residence, pellet size and productivity. The size and shape of the drum should be such as to obtain to most favorable conditions of motion and pressure that is more of rolling as opposed to sliding action. This is a more effective collision between the particles. The capillary action of water in the pores of the ball is sufficiently high so as to compact the constituent grains into a dense mass, the compressive force is directly proportional to the fineness of grain. Since, the capillary action rises with the decrease in

the pore radius and the later decrease with increasing fineness. Optimum moisture is important since too little of water introduced air inclusions in the pores in too much of water cause flooding and destruction of capillary action. The optimum moisture content lays between 5-10%, the finer the grains the larger the requirement.

2.4 Carbonization

The carbonization stage may be decisive in charcoal production even though it is not the most expensive one. Unless it is carried out as efficiently as possible, it puts the whole operation of charcoal production at risk since low yields in carbonization reflect back through the whole chain of production as increased costs and waste of resources. Wood consists of three main components: cellulose, lignin and water. The cellulose and lignin and some other materials are tightly bound together and make up the material we call wood. The water is adsorbed or held as molecules of water on the cellulose/lignin structure. Air dry or "seasoned" wood still contains 12-18% of adsorbed water. Growing, freshly cut or "unseasoned" wood contains, in addition, liquid water to give a total water content of about 40 to 100% expressed as a percentage of the oven dry weight of the wood. The water in the wood has all to be driven off as vapour before carbonization can take place. To evaporate water requires a lot of energy so that using the sun to pre-dry the wood as much as possible before carbonization greatly improves efficiency. The water remaining in the wood to be carbonized, must be evaporated in the kiln or pit and this energy must be provided by burning some of the wood itself which otherwise would be converted into useful charcoal. The first step in carbonization in the kiln is drying out of the wood at 100°C or below to zero moisture content. The temperature of the oven dry wood is then raised to about 280°C. The energy for these steps comes from partial combustion of some of the wood charged to the kiln or pit and it is an energy absorbing or endothermic reaction. When the wood is dry and heated to around 280°C, it begins to spontaneously break down to produce charcoal plus water vapour, methanol, acetic acid and more complex chemicals, chiefly in the form of tars and non-condensable gas consisting mainly of hydrogen, carbon monoxide and carbon dioxide. Air is admitted to the carbonizing kiln or pit to allow some wood to be burned and the nitrogen from this air

will also be present in the gas. The oxygen of the air is used up in burning part of the wood charged. The spontaneous breakdown or carbonization of the wood above a temperature of 280°C liberates energy and hence this reaction is said to be exothermic. This process of spontaneous breakdown or carbonization continues until only the carbonized residue called charcoal remains. Unless further external heat is provided, the process stops and the temperature reach a maximum of about 400°C. This charcoal, however, will still contain appreciable amounts of tarry residue, together with the ash of the original wood. The ash content of the charcoal is about 3-5%; the tarry residue may amount to about 30% by weight and the balance is fixed carbon about 65-70%. Further heating increases the fixed carbon content by driving off and decomposing more of the tars. A temperature of 500°C gives a typical fixed carbon content of about 85% and a volatile content of about 10%. The yield of charcoal at this temperature is about 33% of the weight of the oven dry wood carbonized - not counting the wood which was burned to carbonize the remainder. Thus the theoretical yield of charcoal varies with temperature of carbonization due to the change in its content of volatile tarry material. It is the process of heating a carbonaceous material in absence of air to a sufficiently high temperature so that the material undergoes decomposition yielding a residue having higher carbon content than the original material.

The carbonization of wood is characterized by several temperature regimes

- Firstly all loosely bound water is evaporated between 100^0c and 170^0 C.
- Gases containing carbon monoxide and carbon dioxide and condensable vapors evolve between 170^0c and 270^0c.
- An exothermic step starts at 270^0c and 280^0c, which can be detected by the spontaneous generation of heat and the increase in temperature. the evolution of the oxides of carbon ceases but more and more of the condensable vapor forms.

2.5 Classification of carbonization system

This method should be the most efficient since the heat is generated where it is needed, using low cost wood fuel. In practice, it is difficult to control the combustion and some extra wood is burned which lowers the yield.

Indirect (external) heating allows more precise control but to transmit the heat to the charge is difficult and inefficient and metal retorts are almost essential. By-products can be recovered free of contamination from the products of combustion. A hybrid method heats the charge of wood by passing hot gas through it. The hot gas is obtained by burning a fuel which can be wood, oil or gas. Precise control is needed to ensure that the hot gas is free of oxygen, otherwise some of the wood will be burned instead of being merely carbonized. Heat transfer from the hot gas to the wood is quite efficient and where the gases are recirculated under proper control, it is feasible to condense and collect by-products and the combustible wood gas. Systems using internal generation of heat can be further divided by their method of construction. The three possibilities found are earth, which is lowest in cost, bricks or masonry of intermediate cost, and steel which is the most expensive. Steel kilns are further subdivided into portable and fixed types. Steel kilns have two advantages: they can be moved easily, which may be very useful, and they cool quickly, allowing a shorter cycle time. However, portability is not always an efficient idea, since it makes it difficult to organize and supervise production efficiently and fixed brick kilns can be cooled quite rapidly using a slurry of clay and water (with care,) by injecting water spray into the kiln. Although cycle times are still around six to eight days, compared to two for steel kilns, the greater volume and much lower cost of brick kilns make them preferable except where portability is essential. Earth kilns and pits even when operated efficiently, are slow burning and slow cooling and contaminate the charcoal with earth. However, where capital is limited or non-existent, they have real advantages. Kilns heated by an external source of heat are subdivided into those heated by passing hot gases through the charge and those where heat is transferred through the walls of the retort. Most carbonizes in this subdivision are of metal but there is one exception, the Schwartz kiln, still commercially used, which is of brick and heats the charge by pressing hot flue gas from a bonfire burning wood built at the side of the kiln.

Theoretically excellent since low quality wood and bark can be burned, in practice the kiln suffers in comparison to internally fired brick kilns by its high construction cost requiring steel and cast iron components, difficulty of precisely controlling the fire, and sealing the kiln for cooling, leading to air leaks and loss of charcoal.

Steel retorts heated through the walls are not used much today because of high cost and intrinsic low efficiency but some portable and semi-portable experimental retorts have appeared recently (14), e.g. the Constantine retort and the Jamaican oil drum retort. The steel retorts heated by circulating gases are efficient, produce charcoal of excellent quality and allow by-products to be recovered. However, their high capital cost makes them unattractive, except where the labour costs of traditional systems outweigh the high capital cost. These retorts are mainly applied today for making high grade charcoal for metallurgical and chemical use. Their use in the charcoal industry once seemed attractive but recent developments in making high purity iron without charcoal and changes in the world steel industry based on coal, make their use problematic until a lower capital cost version is developed. It seems unlikely that they can make any major contribution to the production of charcoal for domestic use in developing countries.

Having classified the various types of carboniser, they can then be compared, using various calculated indexes (29) such as production per unit of internal volume, unit area of space occupied, unit of capital invested, etc. These calculations are best carried out to compare types within a subdivision when the basic type of carboniser needed has been chosen on broad social and technological grounds. In practice, as far as the developing world is concerned, the choices are limited to deciding between pits, earth kilns, brick kilns and steel kilns, all internally heated. Where capital is the limiting resource, and wood is available, earth kilns are preferable. Where some capital is available and a serious effort is to be made to produce quality charcoal efficiently, brick kilns will probably be preferred. Steel kilns may find use where mobility is of such overriding importance that it overcomes high capital and repair costs.

2.6 Effects of different parameter on carbonization

- Species
- Moisture content
- Wood size
- Carbonization temperature
- Heating rate

2.6.1 Species

Generally all species of wood can be carbonized to produce useable charcoal. There is a variation in the ash content of different woods but this is generally not significant. Bark, however, has unacceptably high ash content and the structure of bark charcoal is too friable to be useful for most purposes. Therefore, where possible, bark should not be used or the amount of bark charged with the wood should be minimized. Softwoods generally produce a softer, more friable charcoal than hardwoods but where available in quantity at a suitable price, they are a good raw material and can produce all types of charcoal. Where a choice of wood supply is possible, such as where plantations are being established to provide wood, it is worthwhile to choose the species and manage its growth rate to optimise charcoal properties. Eucalypt species produce good dense charcoal and are the favoured plantation species for the purpose. Careful tests should be made before unproven, little known species are planted. What counts in the long run is the mass of saleable charcoal produced per unit mass of wood substance. The volume of wood grown per hectare is only a rough indicator of the mass of wood substance produced. A high volume increment may correspond to low density and hence low yield of charcoal per unit volume of wood. Also denser wood usually produces a denser, less friable charcoal. Therefore research to determine what species and what management regime produces the maximum yield of wood substance by weight from plantations is worthwhile. This is an area of active research and definite answers are not yet available. But eucalypts are still the favoured genus.

2.6.2 Moisture content:-

The moisture in biomass not only reduces the net useful energy but also increases the size of the equipment required to convert the biomass energy into a useful form. Therefore, it is highly desirable to reduce the water content of biomass to avoid the waste of energy for vaporizing the water and the added capital cost to purchase larger boiler or gasifier equipment. Figure 1shows quantitatively the impact of biomass water on boiler efficiency and the volume of flue gas per unit of steam, which is proportional to the boiler size.',' In the high moisture range from50 to 60%, the boiler efficiency improves 1% for1% drop of moisture. The magnitude of boiler efficiency improvement decreases to 0.5% for each 1% loss of moisture as biomass moisture content decreases below 40%. Nevertheless, the water in biomass still severely affects the boiler efficiency. The volume of flue gas per unit steam generated is proportional to boiler size. In the mid-range biomass moisture of 40 to 55%, the boiler size increases 2% for 1% increase in moisture in the biomass. Even in the low moisture range of 25-35%, boiler size increases1% for 1% of moisture increase. This increase in equipment size implies a significant increase in capital cost as the moisture of biomass fuel increases. Biomass moisture also inflicts a similar adverse effect on the gasification process, and increases tar formation. It was reported that the biomass moisture reduces both the qualities of the gas and the throughput of the gasifier.3Gas heating value drops dramatically when the moisture content of biomass increases. For instance, if biomass with 50% moisture content at harvest is allowed to dry naturally to 30%moisture, there is a usable heat gain of 1.6 GJ per tonne of dry-matter produced.4Realizing the importance of biomass moisture, many researchers have conducted experiments to find the most economical means to dry biomass. In-field solar drying of biomass requiring little capital and no additional heat energy input was the most frequently researched method. For example, Rogers' conducted in-field drying of logging residues for fuel by delaying logging residue harvesting or by leaving the residues in the field for three winters.

2.6.3 Effect of wood size:-

Carbonization rate is closely related to wood size. Large wood pieces carbonize slowly since the transfer of heat into the interior of the wood is a relatively slow process. Sawdust, for example, can be flash carbonized very rapidly but the powdered charcoal produced is of low market value. On the other hand, large diameter trunks of dense species may shatter when carbonized making the charcoal more friable than otherwise. Studies have shown that charcoal with optimum properties for the iron industry is produced with wood pieces measuring about 25-80 mm across the grain. Length along the grain has little influence. With plantation grown wood uniformity in wood size is possible but natural forests yield a wide range of sizes. Cutting and splitting of wood is costly in labour, fuel and capital and should be avoided wherever possible. For carbonizing large diameter trunks and mixed size charges of wood the slow cycles are best. The pit system is optimum. Of the masonry kilns the slower cycle, larger kilns are best. They are a well proven method for carbonizing large diameter (around 0.5 m) dense wood from natural forests. Trouble in carbonizing can be reduced by placing the large diameter blocks in the centre of the charge. Metal kilns which lose much heat through the walls and cool quickly are ineffective in carbonizing large section wood. The cost of cutting up wood is a serious and growing one as fuel, labour and capital costs increase and this favours the use of earth pits, mounds and brick kilns. It is also usually easier and faster to charge kilns with large size wood, especially if its length conforms to the size of the kiln, pit or mound. It is worthwhile carefully studying the relation between growing, harvesting, drying and kiln charging to decide the optimum dimensions of the wood both in length and diameter, so that overall handling and carbonizing costs are minimized and charcoal of optimum properties for the final end use is obtained. Poor rural dwellers who cannot afford saws and axes often convert large diameter wood to charcoal so that it can be broken up for use in cooking fires. When the relative efficiency of wood to charcoal conversion and burning efficiency of wood and charcoal cooking fires are compared, the practice has much to commend it. Further charcoal is dry and can be stored indefinitely without deterioration. Calculation shows that carbonizing large diameter wood and burning the charcoal is about twice as efficient thermally as burning the wood direct in an open cooking fire. Furthermore, ithout axes, saws and wedges, large diameter wood is unused and may rot before it can be burned.

2.6.4 Effect of carbonization temperature:-

Low carbonization temperatures give a higher yield of charcoal but this charcoal is low grade, is corrosive due to its content of acidic tars, and does not burn with a clean smoke-free flame. Good commercial charcoal should have a fixed carbon content of about 75% and this call for a final carbonizing temperature of around 500°C. The yield of charcoal also shows some variation with the kind of wood. There is evidence that the lignin content of the wood has a positive effect on charcoal yield. High lignin content gives a high yield of charcoal. Therefore, mature wood in sound condition is preferred for charcoal production. Dense wood also tends to give a dense, strong charcoal, which is also desirable. However, very dense woods sometimes produce a friable charcoal because the wood tends to shatter during carbonization. The friability of charcoal increases as carbonization temperature increases and the fixed carbon content increases as the volatile matter content falls. A temperature of 450 to 500°C gives an optimum balance between friability and the desire for high fixed carbon content.

Table 2.1 Effect of carbonization temperature on yield and composition of charcoal

Carbonization Temperature	Chemical analysis of charcoal		Charcoal yield based on oven dry wood
°C	% of fixed charcoal	% volatile material	(0% moisture)
300	68	31	42
500	86	13	33
700	92	7	30

The many variables possible in carbonization make it difficult to specify an optimum procedure - generally the best results will be obtained by using sound hardwood of medium to high density. The wood should be as dry as possible and usually be split to eliminate pieces more than 20 cm thick. Firewood which will be burned up inside the kiln

or pit to dry out and start carbonization of the remainder can be of inferior quality and smaller in cross section. Its sole function is to produce heat to dry out and heat up the remainder to carbonizing temperature. One should try and reach a final temperature of around 500°C through the whole of the charge. With pits this is difficult since the air circulation and cooling effects are irregular and cold spots occur. These produce "brands" of uncarbonized wood. Trying to reach a final overall temperature of 500°C with a pit or kiln having poor and irregular air circulation usually results in burning part of the charcoal to ashes, while leaving other parts of the charge only partly carbonized. Hence the importance of using well designed kilns properly operated for an efficient charcoal operation.

2.6.5 Effect of heating rate: -

The effect of heating rate on monolithic pieces of wood can have an effect on the integrity of the final product. Typically wood charcoal is broken and cracked due to shrinkage stresses developed from the surface of the material decomposing faster than its interior. To avoid this, each wood species requires specific carbonization heating rates based on characteristics such as density and permeability. To illustrate
the effect of improper carbonization conditions the following example is given. A piece of white oak ***(Quercus alba)*** measuring 5 cm x 10 cm x 15 cm (radial, tangential, axial) was carbonized at a temperature ramp rate of 20”C/h, up to 500°C. The specimen turned out cracked on all sides. A second piece of white oak (from the same board) was cut and carbonized in the same manner as the first except that a ramp rate of 5”C/h was used. That heating schedule resulted in a crack-free specimen.

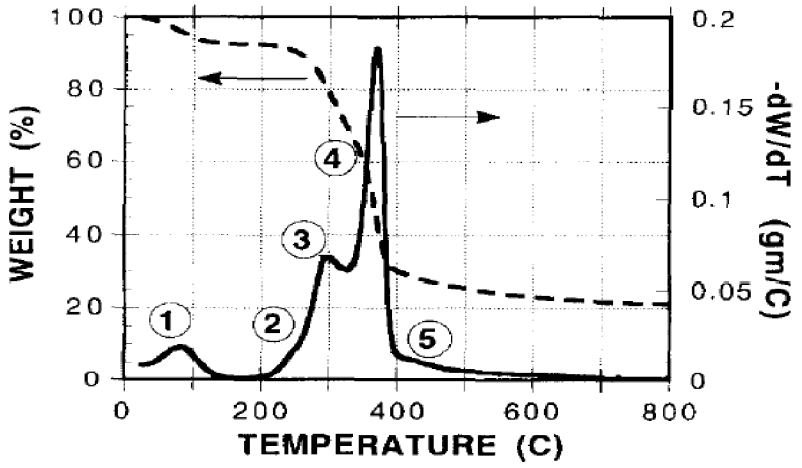


Fig 2.4 Thermo gravimetric analysis (TGA) of hardwood, QZWCUS *rubra* (red oak), with the rate of change in weight with temperature.

Labeled regions correspond to

(1) Loss of absorbed water;

(2) Polymer decomposition begins with hemicellulose component;

(3) Hemicellulose has decomposed, cellulose and lignin begin to dominate rate of weight loss;

(4) Most rapid rate of-decomposition owing to the amount of cellulose and lignin;

(5) The remaining lignin continues to decompose above 400°C.

Fig.2.5. Photograph of carbonized white oak (Quercus *alba)* specimens. Cracking occurred in the specimen on the left from excessive carbonization heating rate.

2.7 Chemical characterization of pyrolysis liquids of wood-based composites

Pyrolysis of wood and wood -based wastes is considered to be one of the promising methods of supplying charcoal as solid material and liquids containing a number of valuable chemicals. In this study, we characterized the chemical components in the liquids from pyrolysis of solid wood and wood -based composites such as particleboard, plywood and medium density fiberboard (MDF) with phenol or urea-type adhesive. In addition, the effectiveness of the liquids to control fungal growth in vitro was examined with consideration of the bio-active components included in the liquids. Results showed that the chemical composition of the liquids obtained from solid wood were greatly different from those obtained from the composites. Fungicidal tests showed a significant difference in the effectiveness of controlling fungi between solid wood and the composites and the liquids from the composites revealed higher effectiveness against the fungi tested. Considerable attention has been focused on the development of processes for producing liquid fuels and carbonized materials from ligno-cellulosic biomass. Today about 14% of the world's energy is derived from biomass providing cleaner synthetic fuels than coal, shale or tar sands however biomass is expected to become a primary energy source within the next 10 years. Liquids from pyrolysis of biomass were given a number of names such as pyrolysis oil, bio-oil, pyrolysis liquid, bio-crude, bio-fuel oil or vinegar. In the past 20 years, reactors for carbonization of biomass such as wood were developed to maximize the yield of liquid products. The liquid products obtained by carbonization or pyrolysis of wood are generally dark brown and viscous liquids, which contain a considerable amount of oxygen. These pyrolysis liquids can also be useful for soil improvement, vermin extermination, and deodorant effects however, it would be helpful to clarify their characteristics to establish new uses such as development of new biocides effective against wood biodegradation. Tree branches, bark, and needles are major components of forestry residue however; sawdust and other wood waste make an important contribution to biomass throughout the whole world. Recycling of wood biomass is valuable issue in the efficient utilization of natural resources and the prevention environmental pollution caused by insufficient disposal of such biomass. Wood waste retired from wooden structures contains not only solid wood

but wood-based composites such as plywood, particleboard, fiberboard which are composed of wood, adhesive and other additives. Pyrolysis products of solid wood show wide variations depending on its chemical components however, pyrolysis liquids of wood based materials might also contain other components derived from adhesives besides regular components from solid wood. Because of complex structure of pyrolysis liquids from carbonization process of wood biomass, they might be expected to protect the wood from fungal and termite attack.

2.8 Advantages of biomass over other alternative sources of energy

- Biomass can be used as a necessary source on decentralized basis.
- Very clean fuel i.e. the ash content varies between 1.0-3.0%
- Energy resource like nuclear power plant or hydroelectric power requires high installation cost.
- Again production of wind energy and solar energy is not viable in all the places.

Some other important application of biomass are-

- Biomass can be used for production of metallurgical coke, which has great importance in metallurgical industries. Ex: - for iron making, gold extraction, for production of some alloys.
- Chemical industries: -in manufacture of ink, activated carbon ,pyrolytic carbon
- Pharmaceutical industries: -for manufacture of medicines.

Apart from these carbonization of wood can be used in advanced material application.

2.9 Wood carbonization and modern materials:-

Unique process for conversion of monolithic wood structures to carbons that retain the cellular structure of the wood without the formation of cracks and other defects associated with charcoal materials is described. A variety of wood species are carbonized to produce the materials which are characterized using TGA, density, dimensional changes, acoustic velocity, SEM and mechanical testing. We demonstrate that through

controlled pyrolysis monolithic carbonized wood can be produced without the macro-cracks normally associated with charcoal. A linear relationship is established between the bulk densities of wood and carbonized wood which spans the entire range of species. For the conditions presented, the carbonized wood had 82% of the bulk density of the precursor wood. Carbonized wood acoustic velocity ranged from 4.7 to 1.3 mm/ps for Tibia americana and Ochroma pyramidale, respectively. Carbonization resulted in decreased acoustic velocity in the axial principal direction and increases in the radial and tangential directions. Acoustic anisotropy was retained through carbonization, but reduced in magnitude. Mechanical testing showed the carbonized wood to be 28% stronger than the precursor. It has recently been demonstrated that net-shape polymer, ceramic and carbon composites can be produced using wood as a precursor. This was accomplished by controlled thermal decomposition to form a monolithic carbon template which retains the anatomical features of the precursor. The carbon tem- plate was shown to be easily machined to net shape prior to conversion to a carbon/polymer composite.

Chapter 3

EXPERIMENTAL WORK

EXPERIMENTAL WORK

3.1 Aim

- The aims of the present project work have been to characterize the proximate analysis and calorific value of different components of BANMICHAI (non woody biomass species).

- The second aim was to carbonize the different components in the temperature range of 300-900°C

3.2 Experimental procedure

- Selection of biomass , (ban-michai) biomass species was collected from the local area.the different components like stem, bark, leaves were collected and separated from each other.the above components were taken in a stainless steel crucible for further analysis.

- The stainless steel reactor was then placed at the required carbonization temperatures of 300,500,700 and 9000 c.

- The reactor was kept there for 1 hr and then the furnace is switched off.

- The sample was allowed to cool in the furnace itself, the chars thus produced were taken out. Then the char obtained was properly grounded and different samples of -72# size were collected and processed for Proximate Analysis & Char Yield Calculation.

3.3 Proximate Analysis

The proximate analysis determines the moisture, ash, volatile matter and fixed carbon.

3.3.1 Moisture content: - Moisture content is usually determined by observing the loss in weight of the sample on heating to about 110°C. In this 1g of finely powdered air dried sample is taken inside a crucible.

Percentage of moisture= loss in weight *100/Wt. of sample taken

3.3.2 Volatile matter: - The dried sample left in crucible (1) is then covered with lid and placed in an electric furnace maintained at 925+20˚C the crucible is taken out after 7 minutes.

Percentage of volatile matter= loss in wt. due to removal of V.M/wt. of sample taken

3.3.3 Ash content: - The residual sample in the crucible is then heated without lid in a muffle furnace at 700±50°C for ½ hr. The crucible is then taken out and cooled in a desiccator and weighed.

$$\text{Percentage of ash} = \frac{\text{wt. of ash left}}{\text{Wt. of sample taken}} * 100$$

3.3.4 Fixed carbon: - Percentage of fixed carbon

=100- % of (moisture + volatile matter + ash)

Chapter 4

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

Table-4.1 Proximate analysis and Calorific values of Chars obtained from (Banmichai) BRANCH

Effect of Carbonization Temperature

Carbonization temperature	Soaking time	Char yield	Proximate analysis				Calorific value
			%Moisture	%V.M	%Ash	%Fixed carbon	
300	1	27.76	5	27	7	61	6638
500	1	22.00	8	16	8	68	6734
700	1	17.29	9	15	8	68	6843
900	1	17.73	9	13	9	69	6207

Table-4.2 Proximate analysis and Calorific values of Chars obtained from (Banmichai) BARK

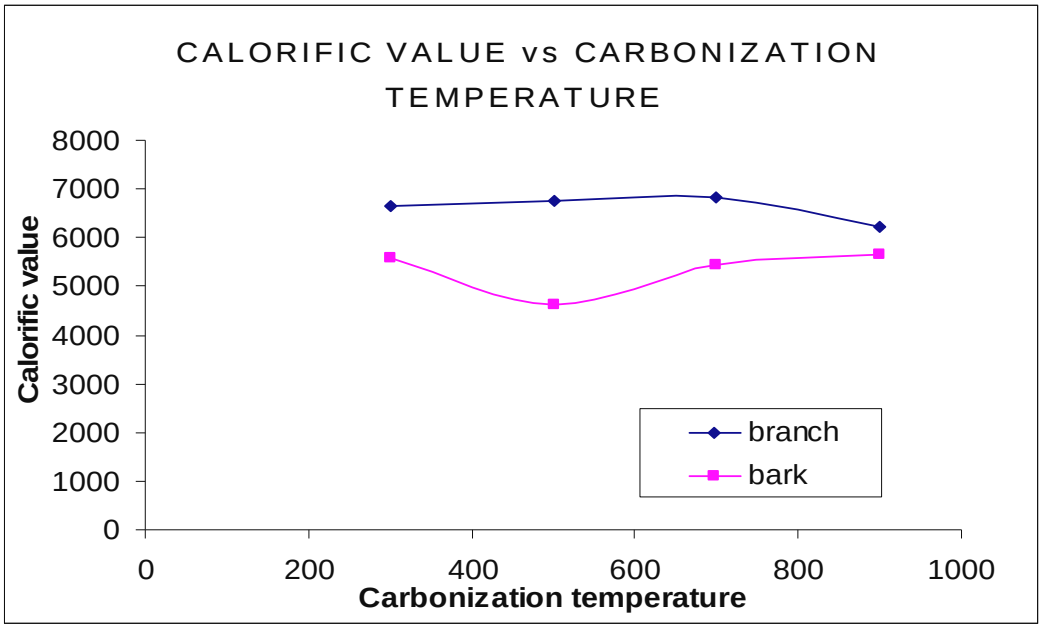
Effect of Carbonization Temperature

Carbonization temperature	Soaking time (hr)	Char yield	Proximate analysis				Calorific value (Kcal/Kg)
			%Moisture	%V.M.	%Ash content	Fixed Carbon	
300	1	27.76	5	27	7	61	6634
500	1	22.00	8	16	8	68	6738
700	1	17.29	9	15	8	68	6843
900	1	17.73	9	13	9	69	6207

Table-4.3 Proximate analysis and Calorific values bark (Banmichai)

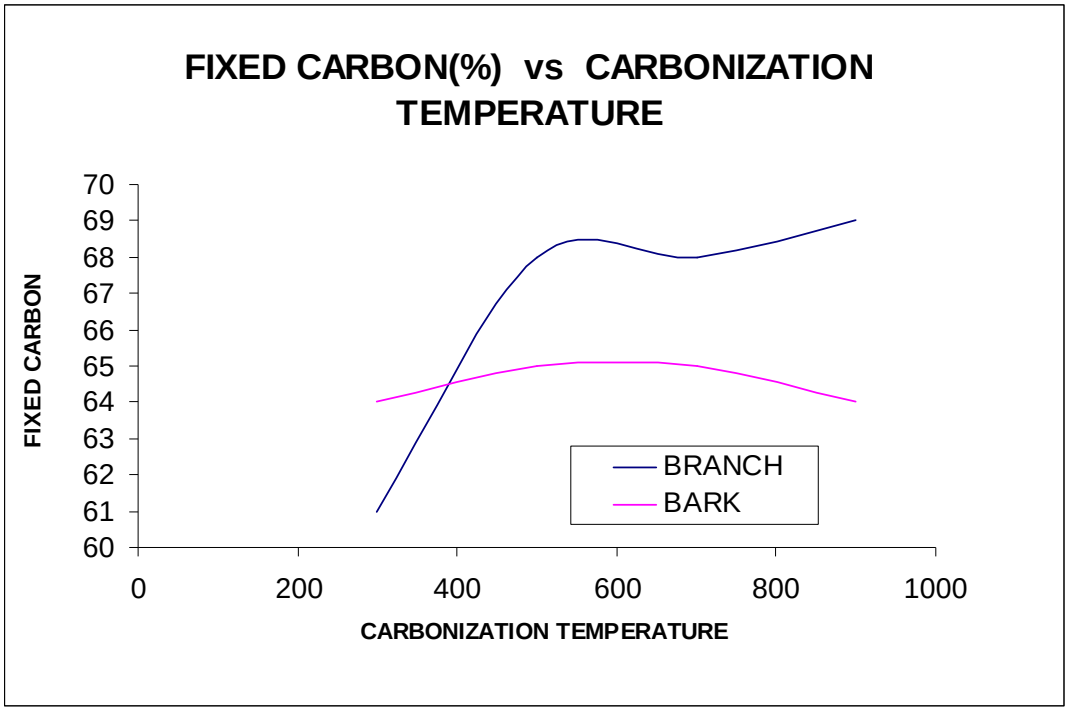
Carbonization temperature	Soaking time (hr)	Charyield	Proximate analysis				Calorific value (Kcal/
			%Moisture	%V.M.	%Ash content	Fixed Carbon	
300	1	46.22	6	24	6	64	5580
500	1	24.79	4	27	4	65	4640
700	1	21.51	3	29	3	65	5423
900	1	11.20	2	31	2	64	5768

Fig:4.1 Graph plotted Calorific value Vs Carbonization temperature



The relationship between calorific value and carbonization temperature has been represented in table:-1 and 2 and in the above figure. From the data obtained from different experiments conducted it is clearly evident that as the temperature increase from 3000 c to 9oo0c there is an increase in the calorific value from about 6600 to 7000 kcal/kg.

Fig 4.2 Graph plotted between Carbonization temperature Vs Fixed carbon



The relationship between fixed carbon and carbonization temperature for both the branch and bark has been represented in the table:-3 and the figure above. From the data obtained it is clearly evident the increase in fixed carbon percentage is more pronounced in case of branch compared to bark which increases from 61 to 69%.further with increase in carbonization temperature the fixed carbon percentage increases significantly in case of both branch and bark**.**

Chapter 5

CONCLUSION

5. CONCLUSION

- From the experiments we observed that there is a significant increase in the calorific value with increase in the carbonization temperature. Therefore it is evident that for higher carbonization temperature the biomass species i.e BANMICHAI can suitably be preferred over other conventional sources of energy.
- Further with increase in the carbonization temperature the fixed carbon (%) was also found to increase.
- The calorific value obtained from different chars samples are found to be comparable to coal.
- Any approach towards utilizing the non-woody biomass would be a positive step toward energy and environment crisis.

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